# LETTUCE TEMPERATURES IN A VAN CONTAINER WITH A REVERSE AIRFLOW CIRCULATION SYSTEM

UNITED STATES
DEPARTMENT OF
AGRICULTURE

MARKETING
RESEARCH REPORT
NUMBER 1082

*PREPARED BY*
AGRICULTURAL
RESEARCH
SERVICE

## CONTENTS

| | Page |
|---|---|
| Introduction | 1 |
| Description of USDA reverse airflow van | 1 |
| Procedure | 2 |
| Results | 3 |
| Discussion | 4 |


Issued January 1978

# Lettuce Temperatures in a Van Container With a Reverse Airflow Circulation System

By R. Tom Hinsch, Russell H. Hinds, Jr., and William F. Goddard, Jr.[1]

## INTRODUCTION

Approximately 70 percent of the western iceberg lettuce production presently moves to market by truck-trailer in tightly stacked loads. Lettuce cartons are tightly stacked to provide the trucker a maximum payload, since lettuce is a relatively low-density product.

Most lettuce is vacuum cooled to satisfactory temperatures soon after harvest. In conventional refrigerated trailers, however, the load often warms up during transit, because cold circulating air from the refrigeration unit follows the path of least resistance and bypasses many lettuce cartons in a tightly stacked load. Even with thermostats set at 36° F (2° C) or lower, many refrigerated trailers have arrived at their destination with lettuce temperatures of 40° F (4.5° C) or higher.[2] In railcars, the difference between the warmest and coolest position in lettuce loads frequently has been 6° F (3° C).[3] Because of tightly stacked loads that interfere with air circulation, the ideal temperature of 32° (0° C) for lettuce is generally not attained in commercial shipments.[4] [5] Since most refrigerated trailers provide perimeter cooling when loads are tightly stacked undesirably high temperatures often develop in the center of the load, which may lead to poor product quality on arrival and reduced shelf life.

Air stacking patterns, which allow refrigerated air to move through rather than around, the load, have been developed to help overcome some of these temperature maintenance problems. However, these loading patterns reduce payloads and may increase labor costs for loading. In addition, they may result in damage to both the lettuce and the cartons, which are usually not stacked in columns. Cartons are stronger in column stacks than they are in offset stacks.

The purpose of this study was to determine if lettuce would be maintained at or near recommended transit temperatures in a refrigerated trailer equipped with a reverse airflow circulation system that forces air vertically through a tight-stacked load, rather than around its perimeter.

## DESCRIPTION OF USDA REVERSE AIRFLOW VAN

In the reverse airflow van, designed by U.S. Department of Agriculture (USDA) engineers, the aluminum T-rail floor runners and grooves run crosswise, rather than lengthwise, as in conventional refrigerated trailers. The T-rails are 1½ inches (3.8 cm) high. If this height is exceeded in most conventional floor designs, bending and distortion of the floor can occur as a result of forklift

[1]Hinsch and Hinds are agricultural marketing specialists, Fresno, Calif. Goddard is a mechanical engineer, Orlando, Fla.

[2]Stewart, J. K., Harvey, J. M., Ceponis, M.J., and Wright, W. R. NITROGEN — ITS EFFECT ON TRANSIT TEMPERATURES AND MARKET QUALITY OF WESTERN LETTUCE SHIPPED IN PIGGYBACK TRAILERS U.S. Dept. Agr. Market Res. Rpt. 759, 14 pp. 1966.

[3]Stewart, J. K., and Harvey, J.M. TEMPERATURES, RELATIVE HUMIDITY, AND ATMOSPHERE COMPOSITION IN A MECHANICALLY REFRIGERATED CAR AND A TRAILER LOADED WITH LETTUCE. U.S. Dept. Agr., Agr. Res. Serv. ARS 51-13, 8 pp. 1967.

[4]Stewart, J. K. TRANSPORTING WESTERN LETTUCE — WHAT'S NEW? United Fresh Fruit and Veg. Assoc., 1973 Yearbook, pp. 105, 106, 108, 110.

[5]Kunkle, H. AIR DISTRIBUTION PROVIDES PROTECTION FOR PERISHABLES. Refrig. Transporter 11 (12): 38-39. 1975.

operations. The floor runners terminate 2 inches (5 cm) from each sidewall; the space between the ends of the runners and the adjacent sidewall is used as a drain trough to facilitate cleaning.

The sidewall air circulation plenums are formed by placing a flat liner over the inverted rib panels that make up the true interior sidewall. The inverted ribs terminate in a gradual 90° arc toward the cargo space at the bottom and toward the discharge plenum at the top, resulting in a smooth transition for a 90° change in the direction of airflow. The open-air supply area of each sidewall is about 1 $ft^2$ (930 $cm^2$).

The discharge air supply plenum is in the ceiling along the top of both sidewalls. These ceiling plenums are 6 inches (15.2 cm) deep and are tapered from 2 ft (61 cm) wide at the front to 10 inches (25.4 cm) wide at the rear. Both are attached to the front bulkhead at the refrigeration discharge outlet and supply the sidewall plenums along the entire length of the van. The tapering in the ceiling plenum is necessary to provide a gradual transition and constant pressure along the entire length of the van.

Each of the two refrigeration discharge air outlets has a free face area of about one-half square foot (465 $cm^2$). A blower behind each of these outlets delivers air at a rate of 1,500 $ft^3$/min (42.5 $m^3$/min) at a static pressure of 2.2 inches (5.6 cm) of water. The ceiling and sidewall plenums have a total pressure drop of 0.5 inch (1.3 cm), resulting in a net static pressure of about 1½ inches (3.8 cm) available at the interface between the cargo and the floor.

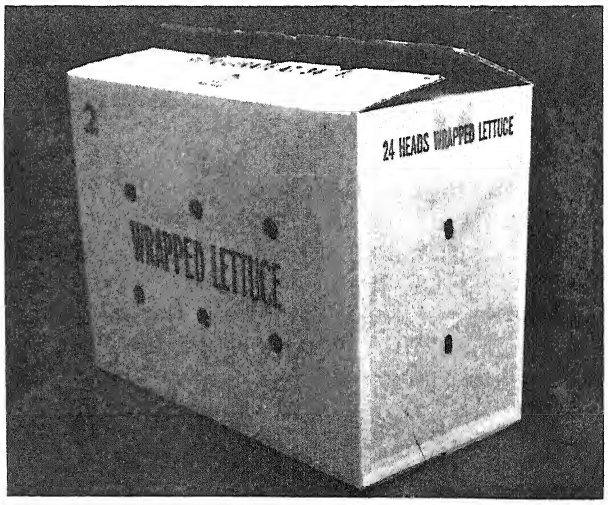
The USDA prototype van is designed to introduce air into the cargo area at a uniform quantity and pressure of 40 $ft^3$/min/ft (3.6 $m^3$/min/m) of cargo length at a static pressure of 1½ inches (3.8 cm) of water. This represents 10 $ft^3$min/$ft^2$ (0.026 $m^3$/min/$m^2$) of floor area at the interface of the floor and cargo.

The thermostat sensing element is located behind the front bulkhead in the return airstream after the air has passed through the cargo.

## PROCEDURE

The performance of the refrigeration unit was evaluated in three tests with cartons of lettuce tightly stacked in the van. The thermostat was set at 34° F (1.1° C). In shipments 1 and 2, the van was transported as a highway truck from southern and central California to the Defense Supply Agency (DSA), Alameda, Calif. The lettuce in these tests was intentionally vacuum cooled to about 40° F (4.4° C) to permit us to evaluate the ability of the refrigeration system to reduce the cargo temperature. In test 3, the van was shipped from central California to the DSA, Tampa, Fla., as a railroad piggyback unit. The lettuce in this test was vacuum cooled to about 34° F (1.1° C).

In the first two tests, the wrapped lettuce was packed in conventional, standup cartons for 24 heads. The cartons had outside dimensions of 22 inches (55.9 cm) long by 11¼ inches (28.6 cm) wide by 16¾ inches (45.2 cm) deep (fig. 1). The cartons were stacked on their sides because the ventilation slots in their sides had to aline with the vertical airflow in the van. In both tests, the van was loaded with 600 cartons of tightly stacked lettuce. Thirty thermocouples were placed throughout the van to monitor air and pulp temperatures for the tests delivered to Alameda (fig. 2).




PN-5801

FIGURE 1. — Conventional standup carton used for wrapped lettuce. Note ventilation holes in the side of this carton.

In test 3, Ryan recording thermometers were used to monitor the air and lettuce pulp temperatures during the 9 days of transit from Salinas, Calif., to Tampa.

This shipment consisted of 750 cartons of let-

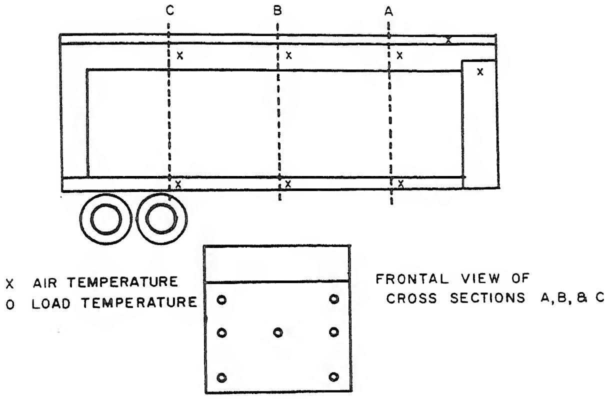
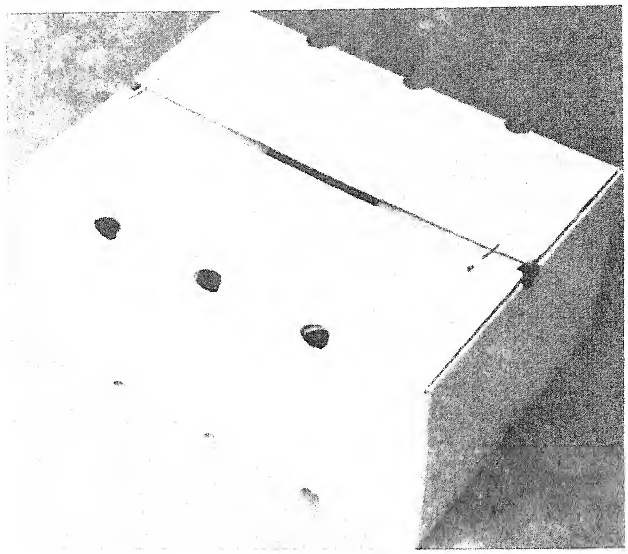



FIGURE 2. — Location of thermocouples used to monitor product and air temperatures in lettuce test. Cross sections at A = ¼ length; B = ½ length; C = ¾ length.



PN-5802

FIGURE 3. — Experimental lettuce carton. Note the special ventilation hole on the score lines of this carton.

tuce, 200 of which were experimental waxed cartons with outside dimensions of 22 inches (55.9 cm) long by 16½ inches (41.9 cm) wide by 11½ inches (29.2 cm) deep (fig. 3). Special 1-inch (2.5-cm) ventilation slots were cut along the edges of the cartons, three slots on the side panels and one on each end panel. The remaining 550 cartons were similar to those used in the first two tests.

The cartons were loaded in the van as tightly as possible in all three tests. Air was forced vertically from the bottom of the top of the load through the ventilation holes in all six layers of cartons. Tight stacking was intended to prevent the refrigerated air from bypassing the cartons.

## RESULTS

The average temperature of the lettuce, when loaded, was 39° F (3.9° C) and ranged from 36° to 43° F (2.2° to 6.1° C) in the two Alameda tests. This higher-than-desirable product temperature was intentionally used to evaluate the ability of the reverse airflow refrigeration system to reduce the cargo temperature in transit, even though the cartons were tightly stacked. After 16 hours, the temperature averaged a nearly uniform 34° F (1.1° C); the range was 32° to 35° F (0° to 1.6° C) (fig. 4). Mechanical failure of the refrigeration unit caused the lettuce to warm between the 16th and 30th hours. However, the temperature was again reduced to a more desired level when the unit resumed operation and remained within ±2° F (1.1° C) of the thermostat setting during the remainder of the tests. After the eighth hour of the test, the discharge air averaged 33° F (0.6° C) except for the period of mechanical failure. These data show that the USDA van can reduce initial product temperatures and maintain them within a desired temperature range without falling dangerously close to the freezing point.

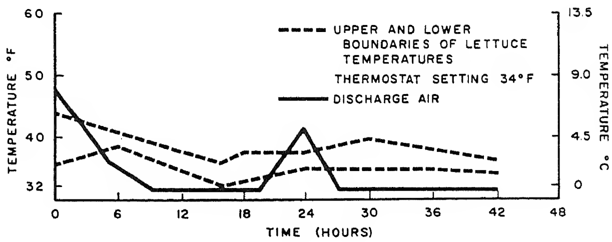



FIGURE 4. — Temperature range of wrapped lettuce in the conventional standup carton and loaded in the USDA reverse air flow van container.

The product temperatures in the railroad piggyback load to Tampa averaged 37° F (2.8° C) when loaded and had a range of 35° to 40° F (1.6° to 4.4° C) (fig. 5). This was a normal commercial load except that all the cartons were tightly stacked in the van. The refrigeration unit reduced the average cargo temperature to 34° F (1.1° C) during the

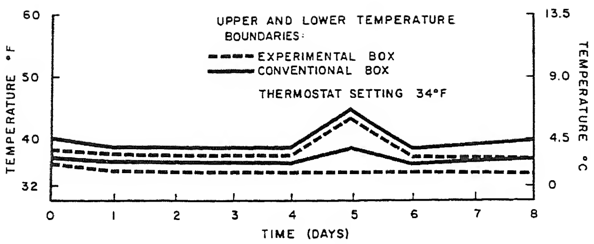



FIGURE 5. — Temperature range of wrapped lettuce packed in an experimental ventilated box and conventional standup box and loaded in the USDA reverse air flow van container.

first 24 hours and maintained it at this level for the entire trip. The cargo temperature rose during the fourth and fifth days because the refrigeration unit was out of fuel.

No discharge air temperatures were available during this test; however, the return air temperatures ranged from 34° to 36° F (1.1° to 2.2° C) during the test, except when the refrigeration unit was off. From previous experience with this unit, we know the return air is usually 2° to 4° F (1.1° to 2.2° C) warmer than the discharge air.

The temperatures in the experimental cartons were about 2° F (1.1° C) lower than in the conventional cartons, probably because of the addition of the ventilation holes described previously.

## DISCUSSION

The ideal transit temperature for lettuce is 32° F (0° C), but 34° to 36° F (1.1° to 2.2° C) is a commercially acceptable range. In many shipments of vacuum-cooled lettuce, the product temperatures are several degrees higher than this acceptable level when loading is completed. Carriers are expected to reduce the product temperature to an acceptable level during transit, but their ability to achieve this depends on four principal variables: (1) Initial product temperature and rate of respiration, (2) ambient temperature, (3) refrigeration unit capacity, and (4) air circulation.

The degree to which a transport vehicle can reduce the cargo temperature and maintain it at the desired level has a direct effect on the condition of the delivered product and, thus, determines the magnitude of any losses that may be sustained. Therefore, it is important that shippers properly precool their products and that carriers use the best equipment to maintain desirable transit temperatures.

The data indicate that the USDA reverse airflow circulation system, designed especially for fresh fruits and vegetables, helps achieve the goal of maintaining uniform temperatures throughout the load.

U. S. GOVERNMENT PRINTING OFFICE : 1977 O - 249-848